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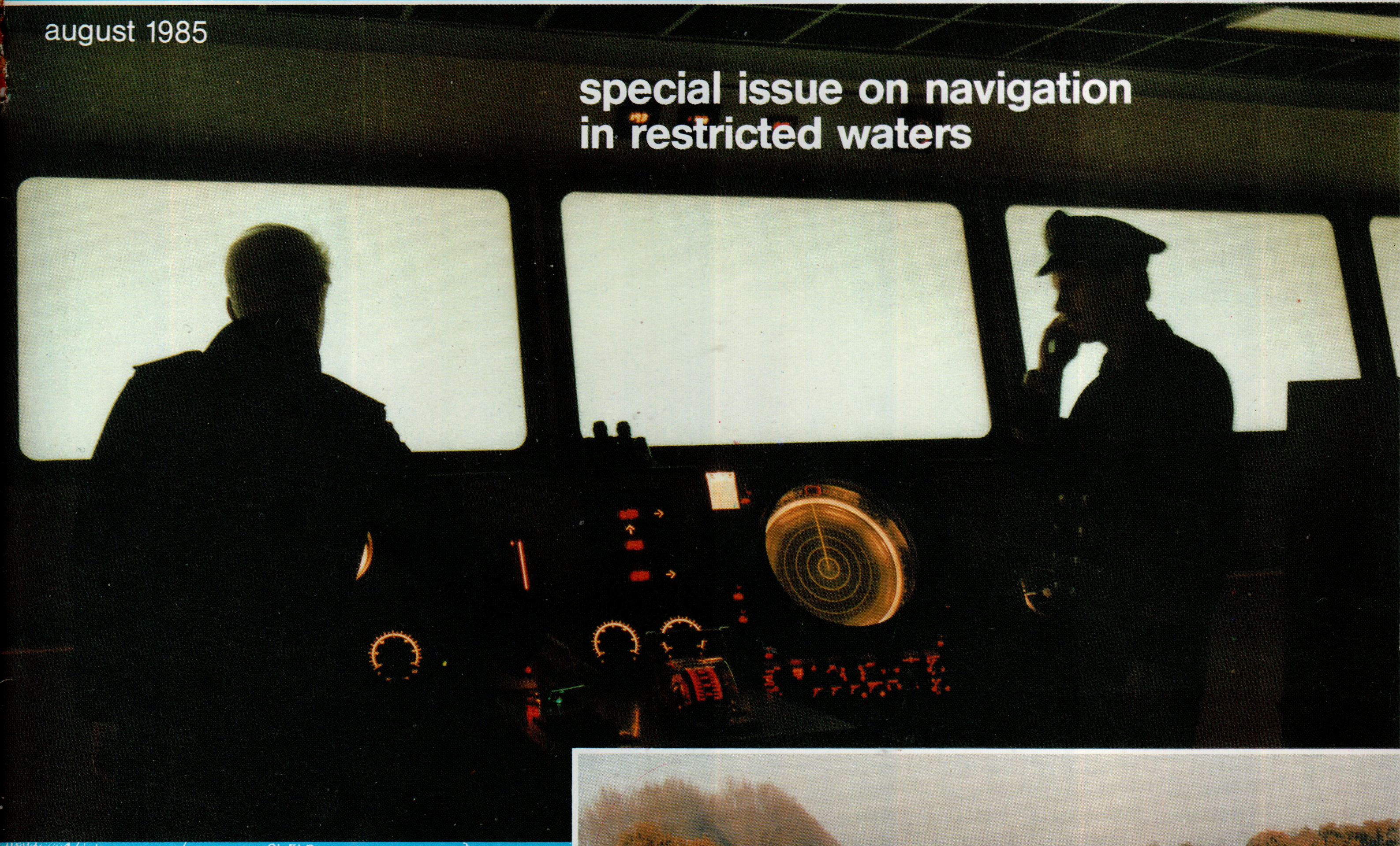

special issue on navigation in restricted waters

delft hydraulics laboratory

hydro delft

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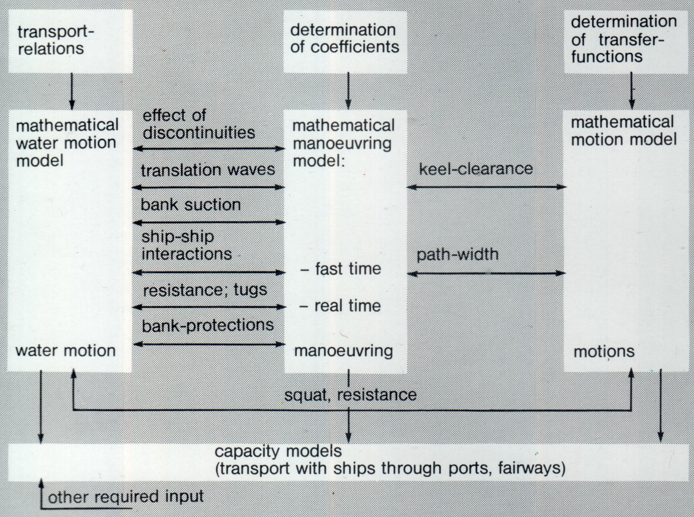
Contents No. 71, August 1985

Special issue on
Navigation in restricted waters

Civil engineering and nautical knowledge especially meet in the design, construction and management of ports and waterways.
In the last twenty to thirty years, research on the navigability of waterways and the accessibility of harbours has developed into a "mature" discipline within the framework of hydraulic research.
This development is characterized by integration with the traditional civil-engineering disciplines, which has resulted in specific research products of the Delft Hydraulics Laboratory.
This issue of HYDRO DELFT covers the behaviour of ships plying restricted waters. The special research products, in fact results of our integral approach to improving navigability, are highlighted.
The system of a ship moving in restricted water consists of the ship and the water both moving within the boundaries of a waterway. The ship is a partially-immersed body, the orientation of which can be changed by activation of its rudder. It moves unter the action of forces caused by its own variable propulsion, by pressures of the moving water,

Navigation in restricted waters



by wind, by tugs, by mooring lines and by fenders. The motions of the water (flows and waves) have various causes, one of which is the moving ship itself. Besides the ship, these motions also exert forces on the boundaries of the body of water which may include structures such as revetments, dolphins, quays and floating objects. Froude already recognised the great role of gravity in the complex interaction of a ship with its surroundings.
Apart from its intended manoeuvres, a ship shows translations and rotations with respect to all three co-ordinates (squat, roll, pitch, etc.) induced by flows and waves but also reduced and damped by the added mass of the surrounding water. The depth and width of the water affects these interactions. The water motions affect the banks and the bottoms of waterways.

"Don't crack wallnuts with a sledge hammer" summarizes our philosophy regarding research tools; use the proper tool for a certain situation.
Consequently, we have developed a broad range of tools varying from the very simplest model to complex analytical and numerical procedures, for example:
- rules of thumb;
- small-scale model tests and full-scale measurements;
- fast-time simulation calculations; and
- real-time simulations.

The choice of the method depends on the availability of reliable input data, the complexity of the transport chain and the cost of model applications.
Recent developments show a tendency towards real-time computations (simulations).

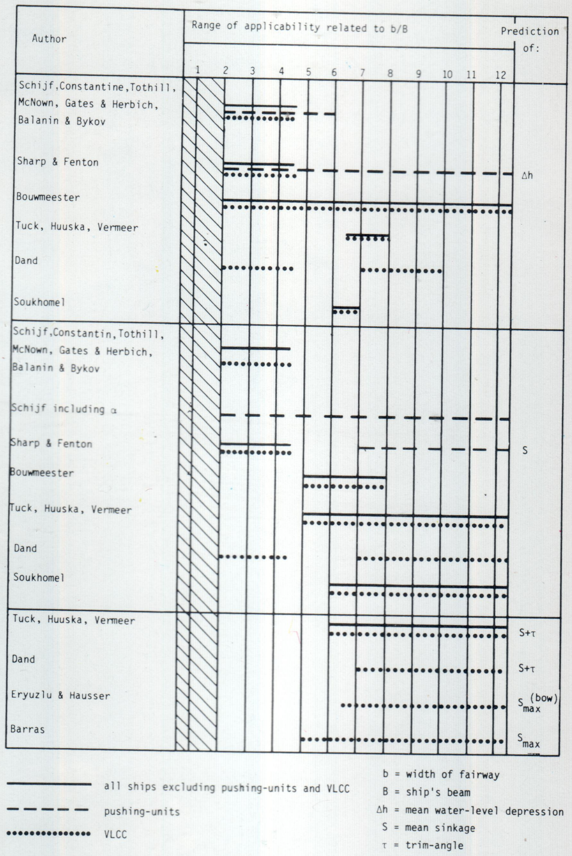
In this issue special attention will be paid to:
- ship-induced water motions;
- ship manoeuvring aspects in relation to the infrastructure;
- ship motion in waves in relation to access-channel depth;
- port simulation models; and
- inland water transport studies including a short survey of tools required.

Ship-induced water motion

Ships sailing in restricted waters are affected by the inherent and induced water motion: the navigating ship thus interacts with her environment. Therefore, it is recognized that knowledge of the ship-navigation.

Ship-induced motions can be classified into:
- primary water motion:
  - water level depressions and
  - return currents
- secondary water motion:
  - transversal and diverging waves and
  - interference peaks of transversal and diverging waves
- screw races.

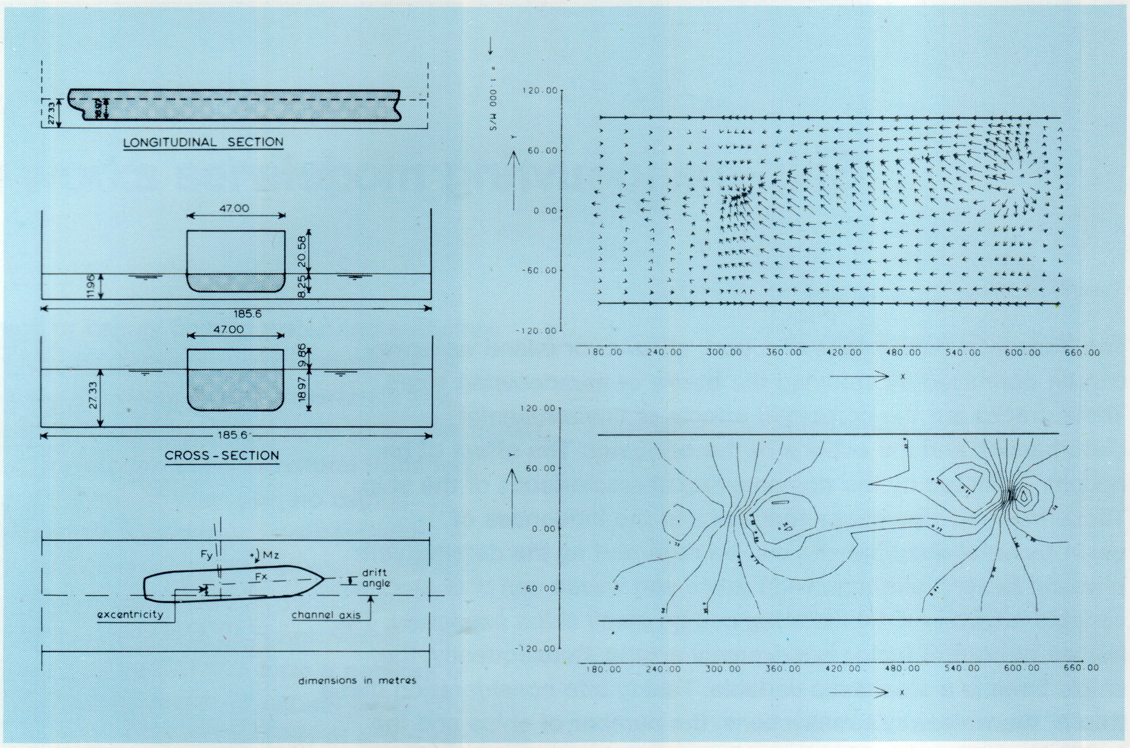
These water motions are investigated by means of small-scale models and full-scale measurements.
Water-level depressions and return currents can be determined by one-dimensional computation methods. Numerous authors have set forth such calculation methods. The phenomenon “squat” is directly related to the ship’s water motions. There are several ways to determine the ship’s squat.

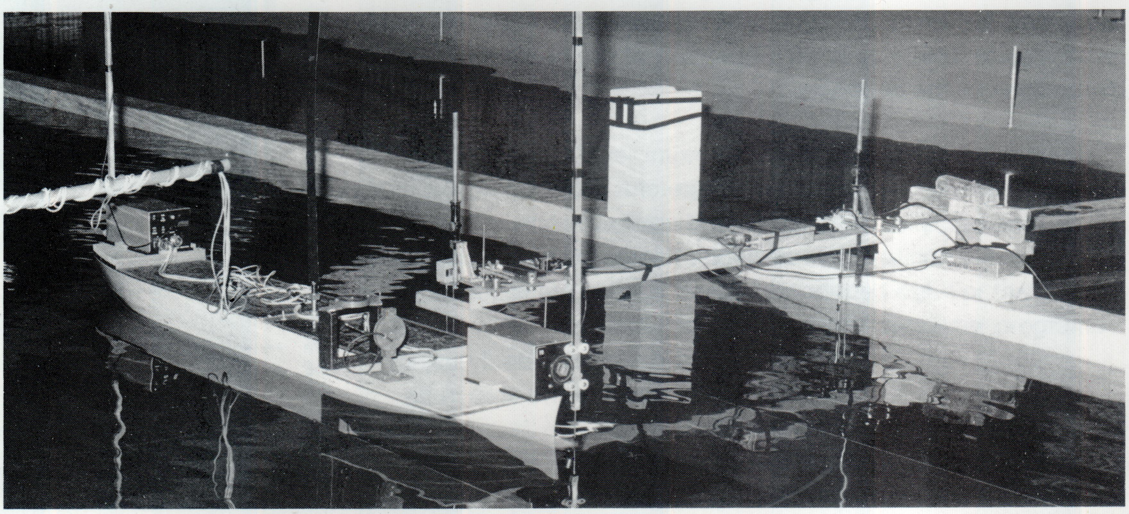


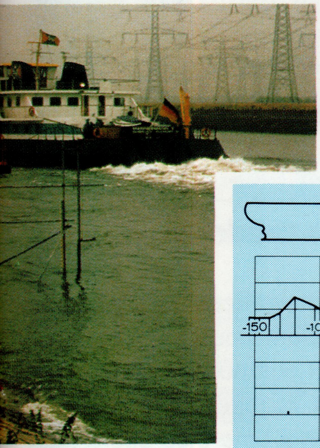
Review of applicability

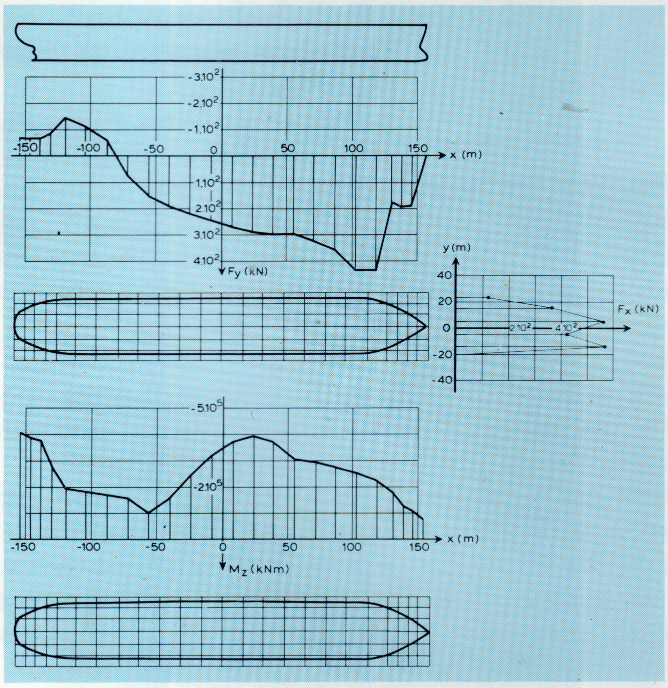
Model investigation on the hydraulic phenomena generated by a push tow on an alluvial river

Forces and moments on a VLCC in a canal







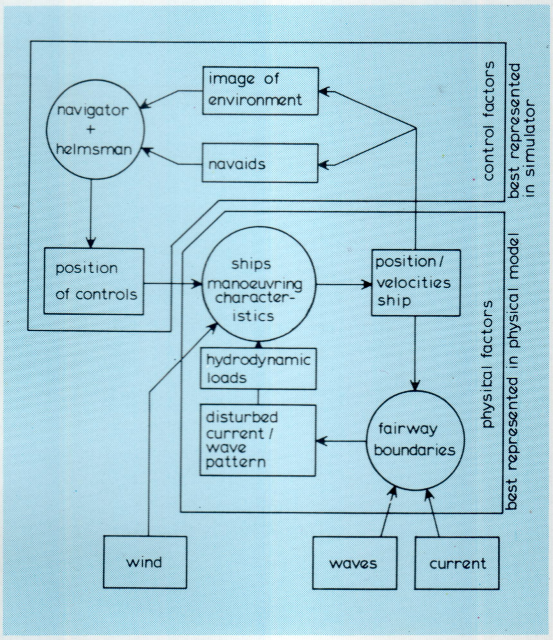


Two-dimensional calculations of ship-induced water motions have become our normal practice. The model developed for ships sailing in restricted waters is based on a depth-averaged two-dimensional flow field. The movement of the ship is represented by a "source" at the stern and a "sink" at the bow, while a rigid "lid" is applied at the free surface.
The resulting pressure distribution around the ship's hull has been used to calculate the water forces and torques on the ship which are important in relation to the ship's manoeuvring. The so-called "bank-suction" is included. This phenomenon occurs whenever a ship sails in laterally restricted waters with an off-set from the centre line.

◄ *Computed velocities and pressures around a VLCC in a canal*

Ship-manoeuvring models

The horizontal dimensions of a port, channel or inland waterway can be optimized by studying the tracks of manoeuvring ships. These tracks are the combined effects of environmental disturbances and the actions of the navigator. The effect of his actions is limited by the manoeuvring characteristics of the ship. These manoeuvring characteristics and the influences of environmental disturbances can be regarded as the deterministic physical factors, although wind gusts and waves can give stochastic variable environmental disturbances on small ships especially. The human or control factor is extremely erratic. Consequently, the ship's track is a stochastic variable. Taking into consideration these tracks, the waterway's restrictions, the number of ships and the traffic lanes, the risk of a grounding or other event can be calculated for various situations. A manoeuvring study will result in an admission policy or in an alternation of the horizontal dimensions of the waterway.



Block diagram of a manoeuvring ship

In the first stage of a project, rules of thumb can give a first approximation of the required channel width. If local physical conditions are critical, detailed studies are required. The manoeuvring behaviour of a ship can be investigated more sophisticatedly using:

- a small-scale model of the ship in its fairway;
- a fast-time mathematical simulation model and/or; a
- real-time manoeuvring simulator.

Small-scale models

Only in special cases use will be made of *small-scale models* in investigating manoeuvrability, because their costs are relatively high. Small-scale model tests nowadays are mostly used for calibrating mathematical simulation models. Special procedures have been developed to determine manoeuvring coefficients. Since recently, these coefficients also can be calculated. A data base of manoeuvring characteristics for different ship classes is available.

Fast-time simulation model (SHIPMA)

SHIPMA combines the mathematical models of the ship's manoeuvring behaviour and the navigator (e.g. auto-pilot). It computes the ship's track, course angles, required rudder action and engine power on a time-step basis. The model can be provided with the following input:

- manoeuvring characteristics of the ship;
- fairway configuration (including depth);
- inherent flow pattern, wind and waves;
- tugs (4 as a maximum) and
- presence of other (nearby) ships.

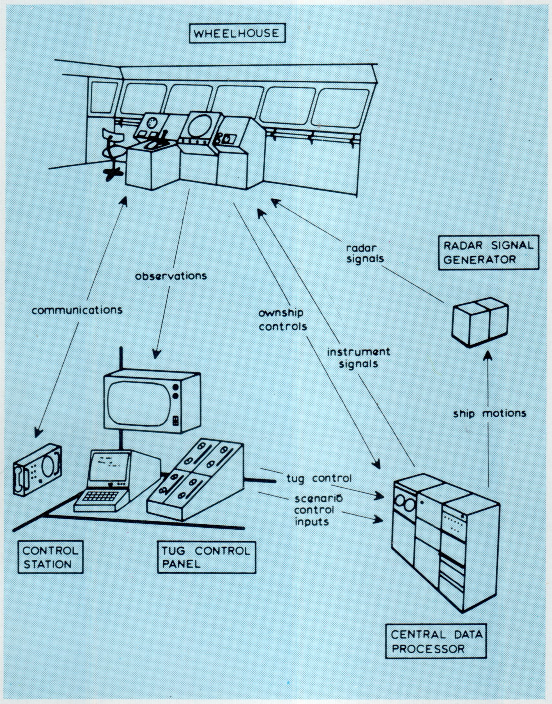
It accounts for influences of wind, waves, currents, water depth and bank suction. Investigations with an auto-pilot steered ship are very useful in comparing various layouts in an early stage of the design.

Simulators

In the manoeuvring simulator, the same mathematical model of the ship's manoeuvring behaviour is used as for the fast-time simulation model. Now the ship is steered on a real-time basis by a helmsman. The navigator performs his task on the mock-up of a ship's bridge equipped with all relevant navigational instruments. This simulator has the advantage that the ship can be steered by local pilots, which gives a more correct representation of the navigator's performance.

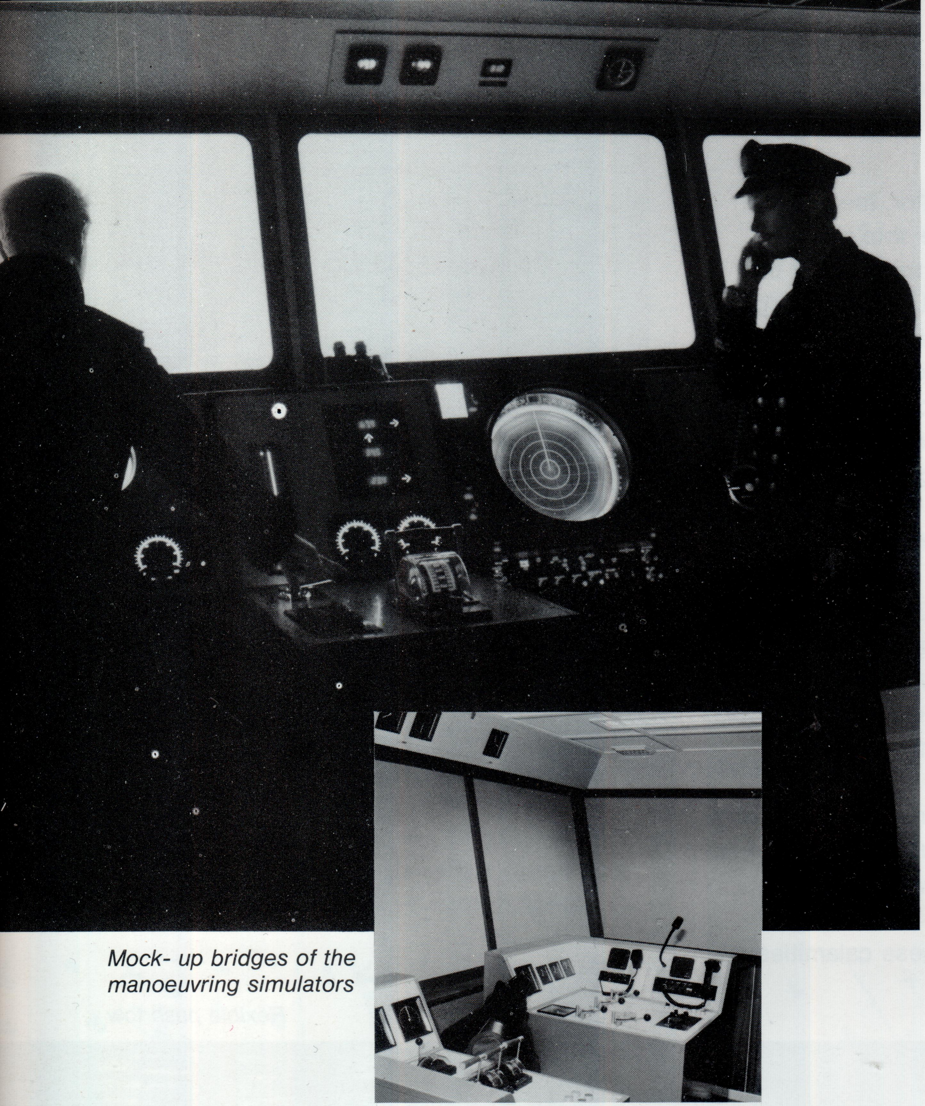
The fairway transit manoeuvres are repeated many times under the same environmental conditions, in order to obtain statistical information on the tracks, resulting in a risk level for the ship to ground under these circumstances.

Another advantage of the real-time simulator is the possibility to introduce calamities. For example, breaking of a tow-cable can be simulated. In these cases, the training of pilots and the effects of these calamities on



System set up of simulator

Flexible push tow



Mock- up bridges of the manoeuvring simulators

the dimensions of the waterway are simultaneously dealt with.
There are three manoeuvring simulating facilities available, each of which is specifically recommendable for particular questions or targets.

The three facilities differ in the way in which information about the status (positions, speeds) of the ship is presented to the navigator.
The *marine radar simulator* is a sophisticated means for training. The visualization of the manoeuvre is very realistic, since it is done by means of a professional radar display. This display is installed in a mock up of the bridge of a large merchant vessel.
The *inland radar simulator* is the inland equivalent of the marine simulator. This facility has been built because the bridge of a modern inland vessel (motor barge or push boat) does not look like a marine bridge at all. Bridges for inland vessels nowadays are designed for one-man control, according to the rules set by ergonomy.
Typical is also the use of a "river-plot", an automatic steering device keeping the rate of turn constant. Of course, all other controls and instruments are provided as well. The application of this simulator is particularly focussed on inland navigational problems like the passage of sharp river bends, berthing manoeuvres at river terminals, entering of harbours, etc.
In addition to the two radar simulators, the Laboratory has a so-called *micro simulator* at its disposal. In this simulator, the information on the ship's position is presented on a computer display as a synthetic radar image and on read-outs of the several instruments. This simulator is applicable to both marine and inland navigation problems. A most remarkable feature is, that this facility is easy transportable, enabling training/education almost everywhere in the world.

Recent commissions of navigation simulations

– port design	– Kalantan (Malaysia) – Bontang LNG terminal (Indonesia) – Eregli Port (Turkey)
– inland navigation	– a feasibility study on hinged pushtows on the River Rhine (Netherlands) – manoeuvring problems in the vicinity of a hydropower plant in Heel (Netherlands) – upgrading the Narmada River (India)
– accident reconstruction	– Van Brienenoordbridge (Netherlands) – Westerscheide (Netherlands) – Waal (Netherlands)
– determination of manoeuvring coefficients for manoeuvring simulation institutes	– general cargo ship on shallow waters – LNG carriers on shallow waters – different pushtow formations (hinged)

Training

Ship motion research facilities can also be used for training purposes! This especially holds for the manoeuvring simulators where training courses in ship handling can be given. To mutually improve their training possibilities, the Laboratory co-operates with the Nautical College of Rotterdam.
The training aims at making people familiar with the ship and the conditions, in order to optimize the execution of the required manoeuvres. This will finally result in:

- capability of handling various types of ships;
- smooth and quick execution of manoeuvres; and
- increased safety for both ships, port equipment and environment.

Tug assistance

In the design and evaluation of the dimensions and the admission policy of ports, the availability of tug assistance can be an important factor.
Normally, a ship has to maintain a minimum speed in order to stay manoeuvrable. The final situation in a port is: berthed with speed zero. This implies manoeuvrability to pass off. The ship can temporarily not defend herself against forces resulting from waves, currents and wind. This is where tug assistance comes in!

In drawing up a procedure for tug assistance, a compromise must first be made between the environmental forces acting on the ship and the required power of the tugs. Aim of the tug assistance procedures is to reduce port downtime. The effectiveness depends on the time during which:
- tugs are available; and
- environmental conditions appear where tug assistance is needed.

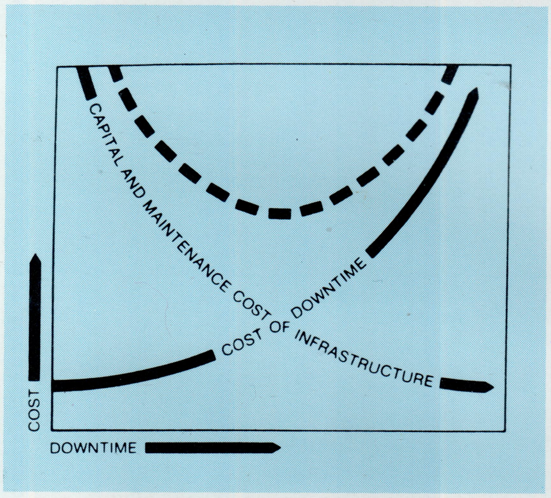
The marine navigation simulator makes it possible to integrate tug assistance procedures for different types of tugs in the fairway and port design. Tug order command can be given by the pilot – by VHF – and tug forces are activated in the system. The behaviour of the tugs is elaborated by the computer after the command has been given.
Generally speaking, the best tug assistance procedure can be obtained by carrying out simulator tests by pilots and tug boat captains familiar with the ships and port under consideration. This approach strongly stimulates the implementation of the procedures.

Channel depth

Both the cost of the construction and operation of a channel are strongly influenced by its depth. Therefore, the determination of the depth of a channel must be an optimization process evaluating both the capital investment (e.g. capital dredging) and port operation cost (e.g. maintenance dredging and downtime of the channel).

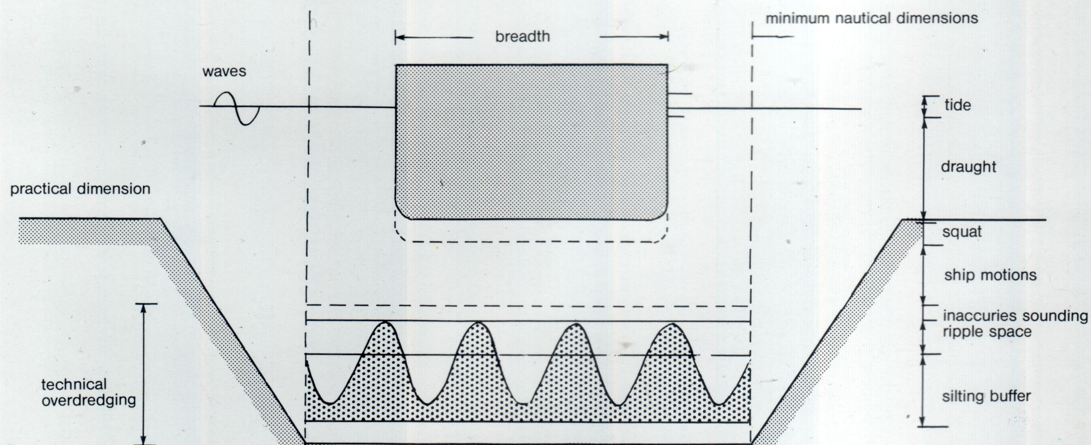
The nautical depth of a channel is determined by the following variables:

- the ship's initial draught and trim, at zero speed;
- fluctuations of the water level due to tides and wind effects;
- squat; and
- the motions of the ship due to waves.



Dredging depth resulting form least needed nautical depth

Information on *hydraulic and weather conditions,* such as waves, currents, wind and tides is indispensable for an accurate determination of the channel depth. Often these have to be collected from field observations, lasting for a period of at least one year.
Ship motions in waves may have a great impact on the final channel dimensions. Of course, this depends on the local wave climate and on the orientation of the channel towards the dominant wave direction.
Knowledge of ship motions in waves can be obtained by experiments with small-scale models or by using mathematical models.
When the investigations on the ship response during channel transit have been completed, the channel depth is determined using all relevant data.
In a probabilistic approach, the stochastic variable of the fleet's times of arrival, draught, transit speed, wave conditions and tides are taken into account. An entrance regime is determined as a function of ship type, wave conditions and water level.
The relation downtime/channel depth can be determined in a frequency domain.
Acceptable downtimes result from an economical evaluation. Once this downtime is known, the channel depth and entrance regime can be determined, e.g. depending on the actual conditions, a bar adder can be issued.
Probabilistic determination of channel depth and optimization of entrance regime has recently lead to the admittance of ships with 72 ft draught in the Euro and Maas channels leading to the Rotterdam port. Other recent commissions concerning the determination of channel depth are: Guayaquil, Ecuador; Beira, Mozambique; Bahia Blanca, Argentina.



Euro and Maas channel study

The probabilistic design technique has been used to determine the channel depth and entrance regime for ships with a maximum draught of 72 feet, entering the Euro- and Maas channel.
In the first stage of this study, the vertical motions of a 375.000 tdw bulk carrier and a partly loaded 500.000 tdw tanker were studied. The ships' motions have been measured for different combinations of ship speed, wave condition and underkeel clearance.
From the test results, the RAO's (Response Amplitude Operator curves) could be computed. These RAO's make it possible to compute also the ship motions in other conditions than those tested.
Consecutively, a computer model (CHOP) was made to optimise the channel depth and to compute the entrance regimes.

Using the results of the model investigations, the chance on hitting the channel bottom during channel passage under prevailing conditions can be computed.

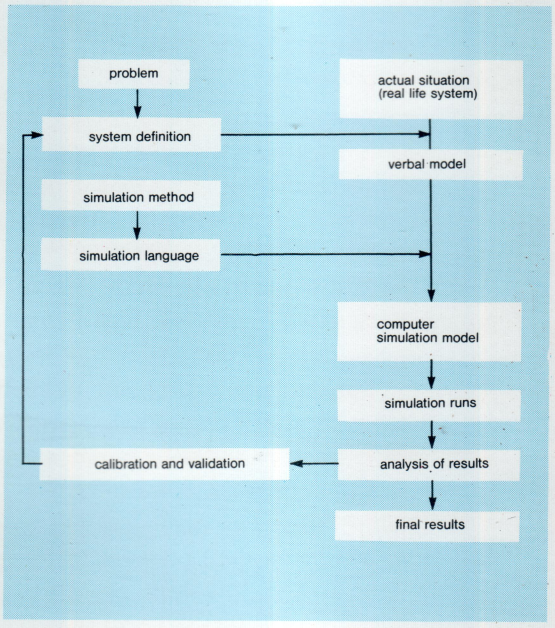
The results of the computations have to fulfill certain safety criteria. These are:

- an average chance of one bottom contact in 2500 passages;
- a maximum chance of one percent of one bottom contact during a channel passage under the most extreme circumstances; and
- a minimum margin of manoeuvrability of one metre.

A check on all possible channel passages against the safety criteria determines the conditions at which a channel passage is allowed and with what tide gate (i.e. navigable period).
This results in tables with tidal gates, as a function of water level and wave conditions. Although specially developed for the port of Rotterdam, the depth of other access channels in the world can also be determined with the program CHOP. As a result of former studies, the RAO's of many ship types are available. If not, these can always be computed using a mathematical model or, when a high accuracy is required, measured in a scale model.

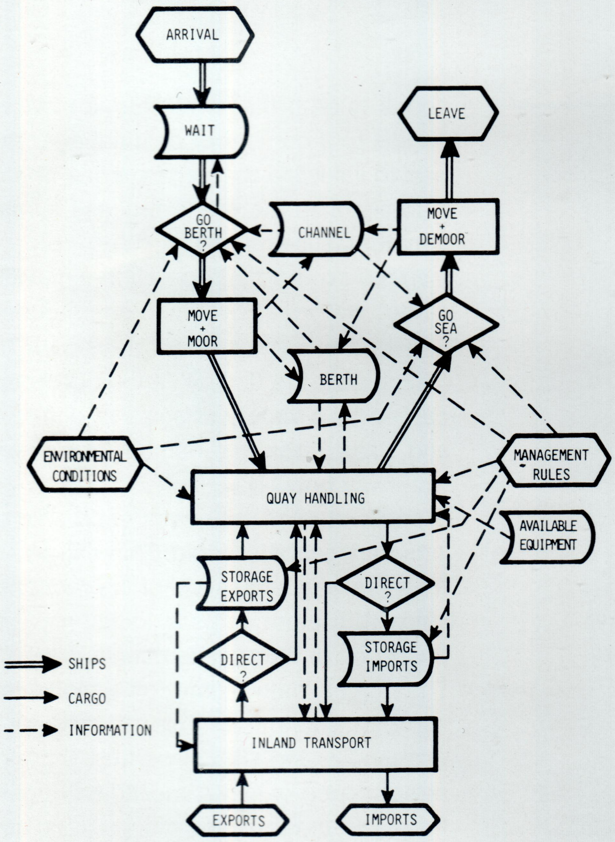
Port capacity and operation

**Restricted waters are met in ports and inland waterways, actually being parts of transport chains.
In order to calculate the effectiveness of measures, it is necessary to study the consequences of these measures in the light of their economical feasibility. The operation and capacity of a water transport chain depends on many highly interrelated factors. Simulation models are becoming more and more a common tool to establish either the most favourable layout or the most efficient utilization of existing facilities and infrastructure by using an actual or forecasted situation. To this end, we have developed capacity models especially applicable for ports and inland waterways.**



Port congestion

The components of the port operation system are introduced in an integral port operation simulation model. In this model a number of modules are related to the movements of ships from sea via the channel and turning basin to the quay and back. Other modules concern cargo flow, such as loading/unloading of vessels, storage and receipt/delivery of cargo by inland transport. Finally, information flows are required to process environmental conditions, priority rules and to process the interactions within the system. Schematically, an integral port simulation model can be represented as shown.



An important criterion for the evaluation of alternatives is minimum total cost, which is mainly determined by investment and operation cost.
Assumptions and input data determine investment costs, output data provide waiting times and equipment usage, thus fixing operational costs. Together with maintenance costs for dredging and equipment these form necessary inputs for an economical evaluation comparing several design alternatives and analyzing their feasibility.
Traffic forecasts are inferred from the general economy.

Management

The tools developed primarily for design purposes, can be very efficiently applied for solving management and operation problems. The capacity simulation models SPORTS and WATRANS can be used to detect causes of congestion and to study the effectiveness of operational changes or limited infrastructural measures.
These models are also very applicable in the training of port managers to adopt the management rules in the most appropriate and effective way.

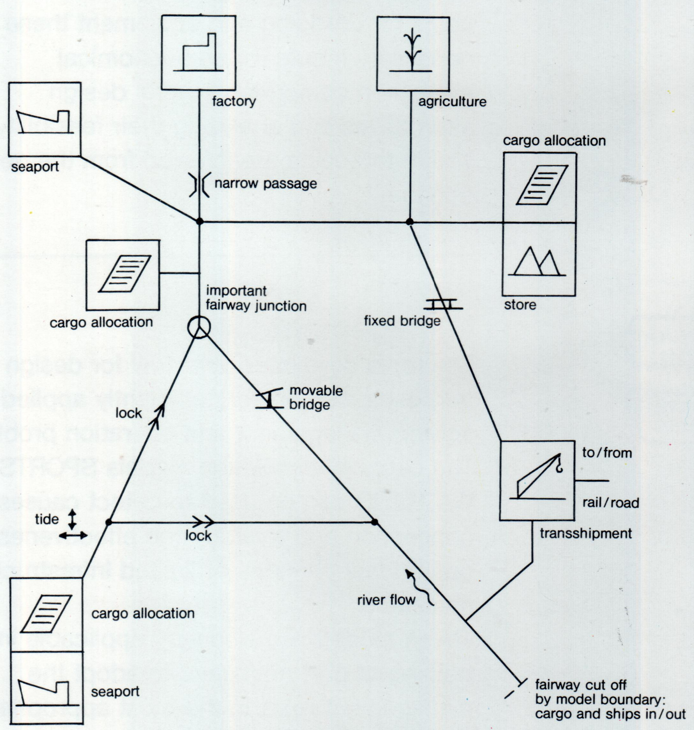
Inland-water transport

Inland-water transport is an important part of the economic activities in a country. The question whether or not inland-water transport should be adapted and developed is mainly a matter of cost and benefit.
Developing a transport system, sometimes simply means removing certain bottlenecks in the waterways and adapting the fleet. Sometimes the transport capacity of the system can be increased by improving the operations. This specially holds for inland waterways in western European countries.

Capacity model

Obviously, there is a strong interaction between the waterway, the fleet and the adjacent infrastructure. Only when they are well tuned to eachother, can the optimum transport performance be realized.
The transport system as a whole has to fulfill a certain task, defined by the quantity of goods to be transported from a number of origins to a number of destinations. The only way to visualize the performance of a system is to simulate the whole process by means of a mathematical model.
Inspired on the port operation simulation model, we have developed an inland-water transport simulator model named WATRANS. It simulates the flow of various cargoes carried by a variety of ships of different types and sizes, through a number of elements of a waterway network.
Step-by-step all actions of each ship are simultaneously followed. This set-up allows for a realistic simulation of interactions of ships with other ships at locks, narrow passages or harbour terminals.
The model finally yields (on a global level) cargo throughput and travel times per commodity and ship class and, more detailed, performance of locks, movable bridges and harbours, in terms of waiting times, queue lengths, occupacy and cargo handling rates.

Scheme of the IWT capacity model WATRANS



The Nile in Sudan

WATRANS can be used on different levels of detail to suit several analysis aims:

- analysis to evaluate capabilities specific for a canal and to determine minimum requirements. Not only the particular canals but also alternative canals and rivers are considered, may be in connection with other modes of transport (by road, rail or air);
- investigation of the canal in isolation with a higher level of detail; sedimentation rates, lock cycles and manoeuvring aspects can be introduced. WATRANS is used to measure the performance of the canal proper;
- one single lock or passage can be simulated with complete details in order to obtain optimal operation rules. Results of studies on high levels of detail can be incorporated in the analysis on a more global level of detail.

The use of one model for all these purposes has the clear advantage of offering one common framework in which all aspects obtain a natural place and by which all results are easily comparable: a systematic approach is easily possible and alternatives can be compared in a structural way.
The simulation finally enables the investigator to identify bottlenecks and to evaluate the impact of all distinct measures.

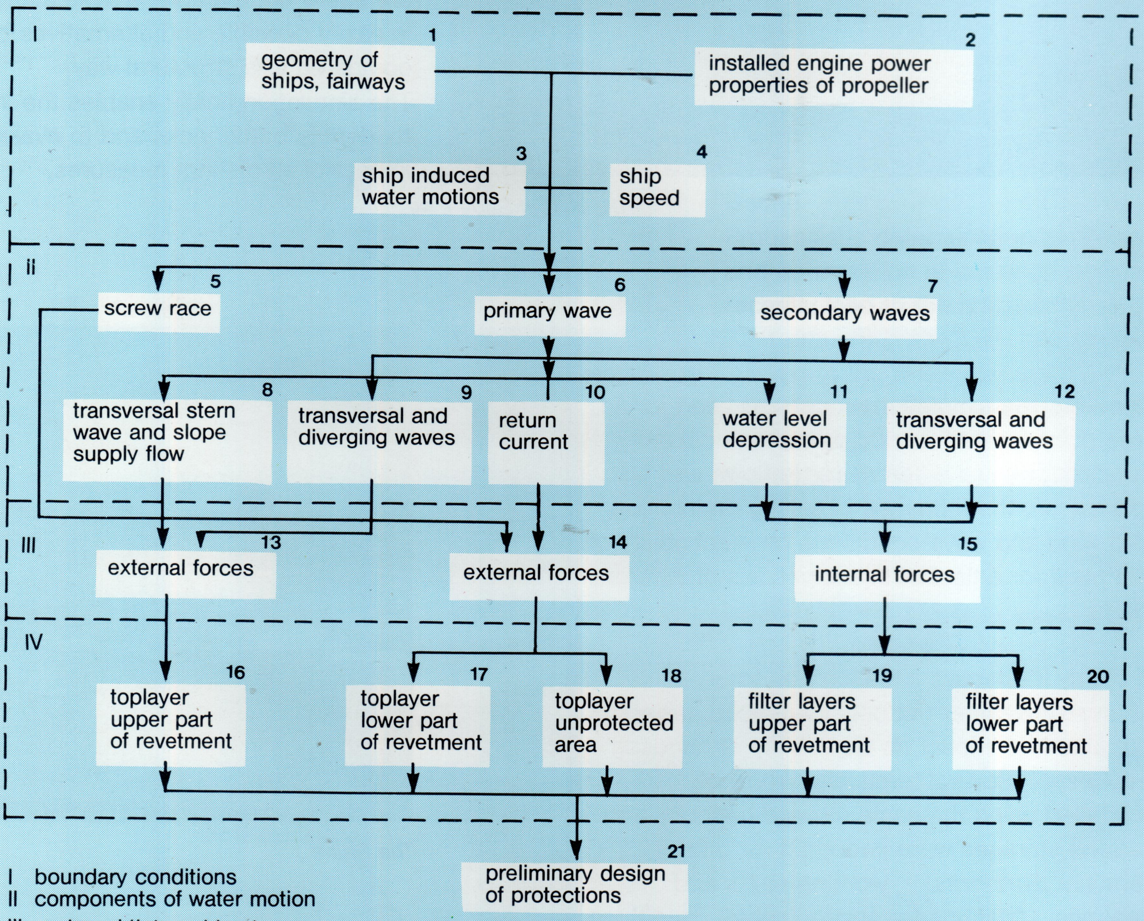
Recently, the simulation model was used for an electricity plant to decide on storage capacity needed for three different cargo flows and also to measure the influence of sailing restrictions and wind and wave conditions on reachability of the plant for a fleet of inland vessels of different kinds.

A highly interactive situation had to be analyzed: weather not only influenced sailing but also had impact on workability of handling equipment. Several terminals had to be modelled using the same storage capacity and several storages were important for one terminal. Furthermore, working shifts and seasonal variations for environmental conditions were modelled. The flexibility of the model proved to be very valuable: some details were left out, other simply fitted in.

The Rhine

Bank protection

Inland navigation has always been of extreme importance. During the last decades, the sizes and engine powers of inland motor vessels have increased particularly since the introduction of pushtow units. The water motion induced by large and fast-sailing ships attacks the banks and the bottom of the waterway more than ever before. The high maintenance and construction costs justify investigations on the interaction between ship-induced water motions and the stability of bank protection structures.
A long-term research program on this subject resulted in design rules.



Ship speed

Interactions between a ship, the fairway and its banks are met in the first step of the design process. The geometry of both the design ship and the canal cross-section, the applied engine power and propeller characteristics determine the ship speed. In order to predict the ship speed, the return current velocity and incremental resistance due to squat have to be accounted, which are in their turn, also depending on the ship speed. Relations for the speed prediction have been determined, based on a wide range of measurements in restricted waterways. Once the speed is known, the ship-induced water motions can be assessed.

Stability of bank protections

The induced water motions are translated into loads on the bank protection, which can, for example, result in displacement of individual stones by shear stresses or lifting of blocks by pressure forces. The bank protection should resist these forces and should prevent the removal of subsoil and/or filter material through the structure. Finally, sliding of the subsoil or parts of the structure must be prevented. Both hydraulic and geotechnical aspects are thus of importance.
A variety of design rules and calculation methods have been derived from small-scale model tests for predicting the necessary resistance of different bank protections like rip-rap and block revetments.
With these rules, bank protections can be chosen which are stable under the attack of ship-induced water motions like primary waves, secondary waves and screw races. Results of full scale tests in canals were used to verify the design rules.
The possibility of a probabilistic design method of bank protection is being studied. An important aspect is the sailing behaviour of ships in a waterway. The stochastic character of forces exerted by the water motions and the strength of the bank protection also plays an important role. It is expected that the probabilistic design method will be a very valuable tool in designing bank protections.

Bank failure due to ship-induced water motions

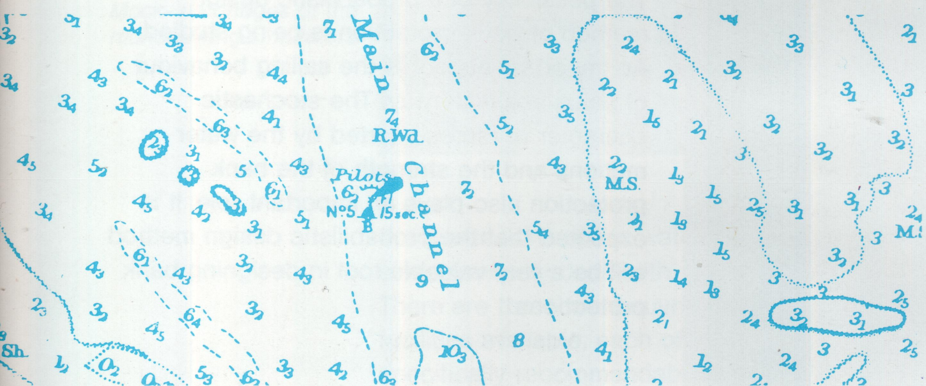
Design process ◄ of a bank protection

Aids to navigation

Studies on river navigation include the manner in which a river channel is to be marked for safe navigation.

Navigational aids can be subdivided into:
- unlighted buoys and light buoys;
- shore-based markers, lighted and/or unlighted;
- stakes on sand bars;
- leading lights and/or leading lines; and
- shore-based radar.

The aids to navigation comprise:
- river charts;
- radio communication;
- ships radar; and
- search lights.



To advise on the above mentioned subjects, knowledge of the local conditions and circumstances is required, such as:
- the physical conditions of the river:
  - characteristics of the river and river banks (channel stability, geometry, vegetation),
  - seasonal changes in water levels,
  - velocities of the currents and
  - bed materials;
- climatic conditions (rain, haze, fog);
- the future plan of development of shipping (economic justification);
- the available finances, other possibilities of funding; and
- the organization (manpower, experience, available relevant equipment).

Trained rivers, (i.e. rivers with a fairly fixed navigable channel) can be subject to the installation of a sophisticated system of beaconage by means of fixed shore markers and lights, illuminated signs and light buoys in addition to more conventional markers and buoys.
Such systems are often a must, since the river has been trained for navigational purposes and in order to take full profit of such investments or in order to use the capacity of the waterway to its full extent.

Most rivers in the world are untrained and have unstable channels. Often the inland-water transport system is still in a developing stage and therefore the applications of a sophisticated beaconage system is not justified. Low cost solutions are sought considering aspects such as the type, number and size of vessels on the river; the dangers encountered and the availability of local pilots.
In many cases, a simplified system of conventional markers and buoys, made of local materials will be very effective.
The Laboratory can also transfer knowledge for the set-up of conservancy services and advices on the required equipment, vessels and materials, as illustrated by the following three project descriptions.

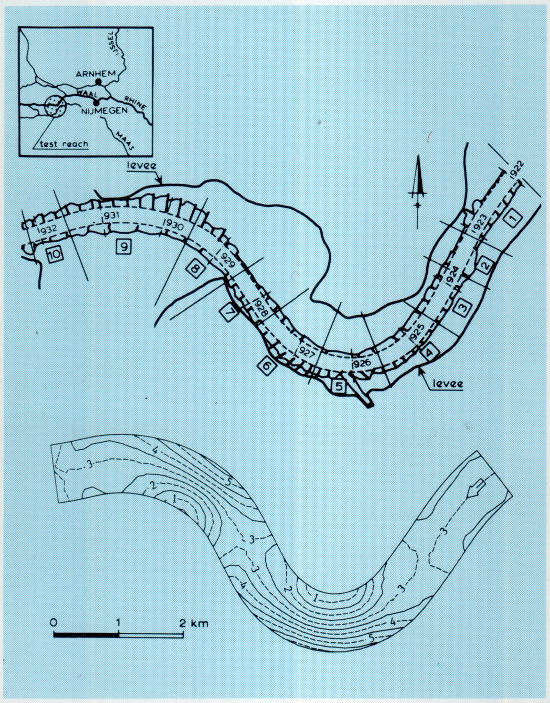
1 Niger and Kainji rivers in Nigeria
Advice was given on the layout of a night navigation system consisting of light buoys, buoys, leading lights and beacons. Along the river, the system had to be diversified considerably due to the varying river characteristics (downstream: stable and deep; mid-river: shallow, sandy and meandering; upriver: steep rocky). Also possibilities of ship-based radar, shore-based radar and radio communications were considered.
The organizational set-up of a conservancy service was proposed including the required manpower, training, equipment (instruments), repair shop and vessels for beaconage, patrol, servicing and surveying.

2 Orinoco river in Venezuela
Advice on selection of a channel-marking and radio communication system.
Assistance by reviewing quotations of suppliers of the required equipment.

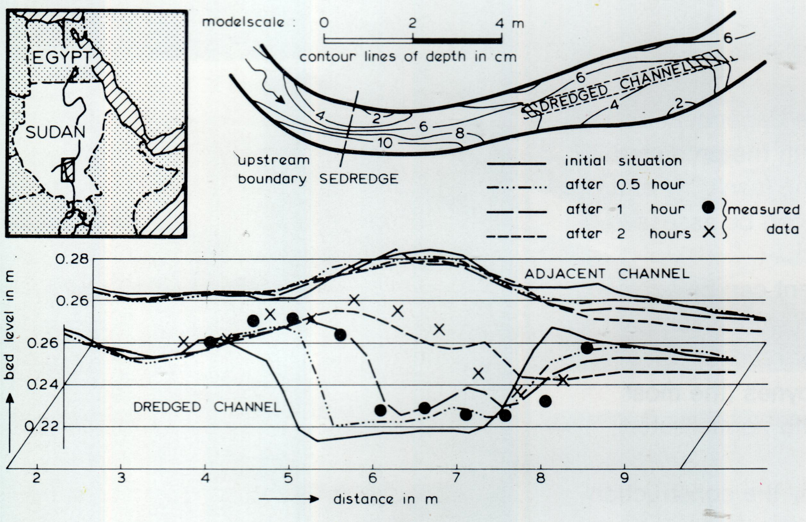
3 Courantyne river between Guyana and Suriname
Set-up (type selection, location) of a marking system consisting of conventional buoys, light buoys and leading lights. A cost estimate was compiled.

Engineering works serving navigation

Navigation needs stagnant or calmly flowing water and sufficient water depth. Waterways can be distinguished in natural water courses, of which especially the rivers are of importance and artificial waterways, of which canals and lakes have to be mentioned. Throughout history, rivers have been used as natural transport routes. In the case of an easily navigable river, no capital investment and no maintenance is required. However, with increasing sizes of ships such rivers become an exception and show many defects in certain reaches and/or during certain periods of the year. River engineering deals with the improvement of waterways. Canals connect river systems to form a network of waterways and they go beyond the reach of natural water courses. Navigational aids and the choice of a proper type of schip can also add to the efficiency of navigation.



Example of simulation with SEDIBO



Simulation with SEDREDGE compared with observations

River improvement studies have to be based on the knowledge of the river characteristics. Available data have to be collected and analyzed and generally, additional river surveys have to be carried out. For the processing of these data computer programs are used.

The dominant factors affecting navigation are the least available depth (LAD), and the width of the navigable channel between the river banks. For the determination of the factors as a function of time and place, it is important to predict the trend of the hydrograph after a flood season. A high predictable hydrograph presents a great advantage to navigation and the other way around. Based on hydrologic, hydraulic and topographic data, this problem is solved by using computer programs for the assessment of probability curves of hydrographs and water-level profiles along the river. After that, the bottlenecks in the waterway can be located and specified.

A first step in the improvement of rivers for navigation is often, due to its flexibility, the repeated dredging of channels through shallow reaches. An important aspect of these operations is that sedimentation in the dredged channels determines the efficiency. The sedimentation can be estimated from computations with 1-D and 2-D mathematical

models describing the time-dependent bed level changes. Together with the predicted trend of the hydrograph, the feasibility and/or optimal dredging strategy can be assessed.

More structural improvement can be achieved by permanent river-training works, such as:

- constriction of wide river reaches, for instance by building groynes (the most extreme case is the width normalisator);
- river bend cut-offs;
- raising the water level by the construction of weirs combined with ship locks (canalization), backing up the water during dry periods;
- regulation of the discharge by the construction of dams with locks.

These works, especially the last two types, are seldom feasible in the case they are not combined with other purposes, such as irrigation, water power, flood control, etc.
The response of the river (hydraulically and morphologically) to these works can be estimated from computations with 1-D mathematical models which can cover large areas.
More detailed information can be obtained from computations with 2-D mathematical models and scale models with a movable bed.

To maintain a continuous connection for navigation, ship passing facilities, such as locks, are indispensable near weirs and dams as well as in canals.
Hydraulic model studies of weirs, locks and dams have been carried out for many waterway systems, as for example:

- **Feasibility of systems**
  - Rhine canalization, the Netherlands,
  - Meuse canalization, the Netherlands,
  - Jonglei structures project, Sudan,
  - Narmada project, India.
- **River training**
  - groynes and training walls,
  - dredging,
  - realignments.

- **Layout of lock approaches**
  - studies on flow patterns, lock entrances and waiting places,
  - studies on inflow and outflow structures, guiding structures and fender forces.
- **Hydraulic performance**
  - filling and emptying systems,
  - salt-fresh water separation systems,
  - discharge capacities and
  - hydraulic shape of culverts and gates.

Let's meet in Washington D.C.!

The 4th International Conference on Numerical Ship Hydrodynamics will be held 24–27 September at the National Academy of Science, 2101 Constitution Avenue, N.W. Washington D.C.

The Program comprises the following sessions:
- linear seakeeping at forward speed
- nonlinear motions/slamming
- seakeeping at zero forward speed
- ship waves and wavemaking resistance
- wavemaking resistance and flow
- submerged bodies and geometry
- viscous flows

The Delft Hydraulics Laboratory will be represented at this conference by Han de Ruiter, project-engineer/physician of our Rivers, Navigation and Structures branch.

Recent Publications of the Delft Hydraulics Laboratory, free available at request:

300 Keuning, P. J.
Calculation method for the behaviour of a cutter suction dredge, operating in irregular waves. (1983).

301 Mol, A./Ligteringen, H./Paape, A., Risk analysis breakwater design. Coastal Structures '83, Washington, March 9–11, 1983, 7 pp., (1983).

302 Blaauw, H. G./ Knaap, F. M. C. van der, Prediction of squat of ships sailing in restricted water. 8th International Harbour Congress, Antwerp. Belgium, June 13–17, 1983, 14 pp., (April 1983).

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304 Blaauw, H. G./Verhey, H. J. Design of inland navigation fairways. Journal of Waterway, Port, Coastal and Ocean Engineering, ASCE, 109(1983)1, Feb., 14 pp., (May 1983).

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306 Delvigne, G. A. L.
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314 Winterwerp, J. C.
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318 Kostense, J. K./Boer, K. den
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319 Vries, I. de/Veul, M. F.
The influence of nutrient availability on the ecosystem behaviour of a salt-water lake.

320 Blaauw, H. G./Knaap, F. C. M. van der/ Groot, M. T. de/Pilarczyk, K. W.
Design of bank protection of inland navigation fairways.

321 Stive, M. J. F.
Energy dissipation in waves breaking on gentle slopes.

322 Verboom, G. K./Slob, A.
Weakly-reflective boundary conditions for two-dimensional shallow water flow problems.

323 Pagee, J. A. van/Smits, J. G. C./ Wit, J. A. W. de
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324 Gilding, B. H. et.al.
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325 Roelfzema, A./Karelse, M./ Struijk, A. J.
Waterquantity and – quality research for the Rhine-Meuse estuary.

326 Heijden, H.N.C.M. van der/ Jong, P. de
Calibration and adjustment procedures for the Rhine-Meuse estuary scale model.

327 Delvigne, G. A. L.
Experiments on natural and chemical dispersion of oil in laboratory and field circumstances.

328 Delvigne, G. A. L.
Laboratory experiments on oil spill protection of a water intake.

329 Verboom, G. K./Vriend, H. J. de
Nested models: Applications to practical problems.

330 Kolkman, P. A.
Considerations about the accuracy of discharge relations of hydraulic structures and the use of scale models for their calibration.

331 Boiten, W.
The V-Shaped short-crested weir with semicircular cross section.

332 Meer, J. W. van der/Pilarczyk, K. W.
Stability of rubble mound slopes under random wave attack.

333 Struiksma, N./Olesen K.W. et.al.
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334 Rijn, L. C. van
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336 Derks, H./Stive, M. J. F.
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DELFT HYDRO is the machine readable version of the monthly abstracts journal Delft Hydroscience Abstracts, supplemented with abstracts prepared by DHL since 1980, but not published. To provide worldwide coverage of relevant literature, over 600 periodicals are scanned, together with all technical reports, conference proceedings, monographs, and other publications received in the DHL libraries, partly via the publications exchange policy of the International Association for Hydraulic Research (IAHR). Much of the material has a very limited circulation. The majority of the processed material is in English, (some 80 %), but also a considerable amount of material in other languages is processed. In most cases an English summary is provided, and if the language of the document is not English, an English (translated) title is always given, next to the original title (if French, German, Dutch, Spanish, or Portugese).

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